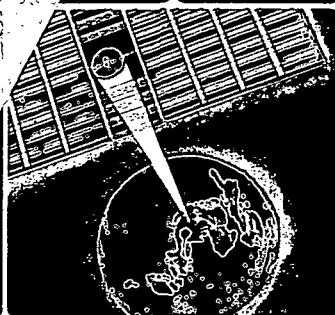
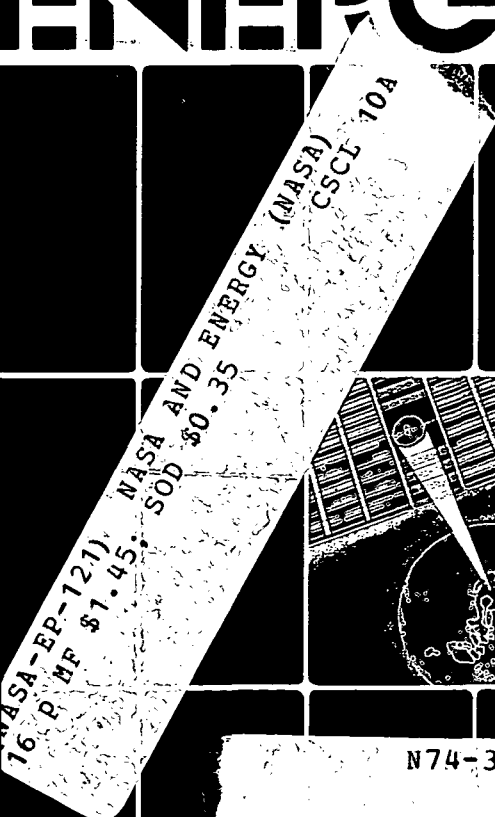




NASA AND ENERGY



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As civilization has advanced, man has had to draw increasingly upon the Earth's reserves of fossil fuels (coal, oil, and gas) to create energy. It took millions of years for natural processes to make these reserves, but man has been using them up in a small fraction of that time.

Whether the exhaustion of these reserves is measured in tens or hundreds of years is irrelevant. What is relevant is that they will be exhausted.

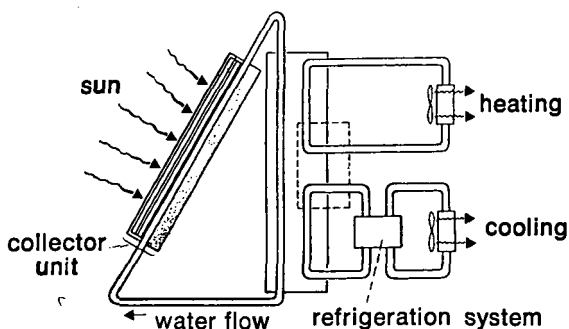
Fortunately, recent events have underscored the urgency of the situation, for it will take a major effort and considerable lead time to develop new, economically attractive, renewable, and environmentally acceptable sources of fuel. NASA technology and skills are contributing significantly to this effort as well as to more efficient use of fossil fuels until new energy sources become generally available.

DIRECT SOLAR HEATING AND COOLING

NASA's work in materials, thermal control coatings, and heating and cooling technology bears directly on the efficient collection and use of solar energy. In the Skylab program, for example, the NASA Marshall Space

Flight Center in Huntsville, Alabama, developed a coating which retains more than 90 percent of the radiation falling on it, permitting increases in operating temperature and efficiency of Skylab's heat-operated refrigeration system. The coating is also economical to apply.

NASA is testing and obtaining realistic experience in direct solar heating and cooling by means of a residential systems engineering demonstration at the Marshall center and the addition of a solar collector system to a new office building at the NASA Langley Research Center, Hampton, Virginia.



Marshall has designed a 135-square-meter (1500-square-foot) solar collector to be installed as a roof over three surplus trailers which have been arranged to simulate a single-family house. The entire experimental system consists of the collector, a storage tank to provide usable thermal energy for as long as three cloudy days, and commercially available, heat-powered air-conditioning and heating units.

The Langley effort calls for installing a 1350-square-meter (15,000-square-foot) experimental collector system as an add-on to a 4500-square-meter (50,000-square-foot) one-story office building under construction. Several different solar collector designs

will be evaluated at this site, giving valuable experience for future systems that will be integrated into building design. NASA goals include halving the costs of current direct solar heating and cooling systems and increasing their lifetimes to beyond 15 years.

NASA's Lewis Research Center, Cleveland, Ohio, is building a facility to test performances of collector components and systems in a variety of simulated building and temperature environments. Lewis will determine the extent to which reliance on solar energy is feasible in different areas and structures.

Nearly all energy available to us is or was solar energy. NASA is developing ways to tap the heat and light of the Sun to meet mankind's future requirements for energy. With an estimated five billion more years of life in its present state, the Sun may be considered an inexhaustible source of fuel.

Probably the first large-scale direct use of solar energy will be in the heating and cooling of homes. About 25 percent of United States current fuel consumption is for heating and air conditioning homes.

Direct solar heating is based simply upon absorption of solar radiation. Loss of heat is minimized by utilizing the greenhouse effect.

Glass is transparent to most of the Sun's radiation but opaque to reflected or emitted infrared (heat) wavelengths from objects under the glass. The glass acts like a one-way valve, admitting light but retaining resulting heat. However, heat is lost by convection as it rises from the absorbing surface to the glass panes, by conduction of heat through the panes, and by radiation from the hot absorbing surface.

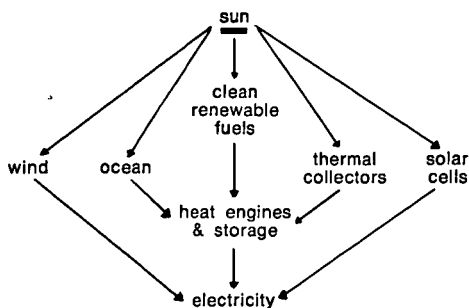
Solar collectors used in systems for direct solar heating of homes aid absorption of heat by means of a black

absorbing surface. Solar collectors reduce conduction losses by having an air space between a double-glass, or double-plastic, cover and by having insulation on all sides. Radiation from the absorbing surface is minimized by use of coatings on the surface that retain almost all the solar radiation that has entered.

Air, water or some other fluid passes through the collector (behind or through the absorbing surface). In the winter, the fluid transports the collected thermal energy (heat) to the building heating system; in the summer, to a heat-powered refrigerator to supply cold water or chilled air for air conditioning. The fluid may also convey thermal energy to an insulated tank where the heat is usually stored in water, rocks, scrap iron, or pieces of concrete until needed for nighttime use.

Direct solar heating and cooling burn no fuel. As a result, they emit no polluting waste products.

Some homes in Japan, the Middle East and in southern parts of the United States have solar water heaters. Water heated by the Sun is stored in huge tanks. A number of buildings in the United States are being heated partially with solar collector systems. The principal problem limiting widespread adoption of direct heating and cooling with solar energy is the



lack of well-engineered, reasonably-priced systems.

WIND GENERATION OF ELECTRICITY

Experts are taking a second look at windmills, which have provided some electricity in many countries for more than half a century. It is estimated that winds in the United States Great Plains area alone would be able to supply about half of the growing United States electrical requirements for years to come. Wind power, of course, is another form of solar energy, as winds are partially due to uneven heating of the Earth by the Sun.

A NASA-National Science Foundation program is aimed at applying new technology developed by NASA in aerodynamics, structures, materials, and power generation to windmill design. The results will be offered to those interested in development of power from windmills.

Windmills can directly spin generators for production of electricity. Or air could be compressed and later used to drive air turbines that would operate generators. The storage system provides available energy for use when the wind dies.

Lewis Research Center will study wind conversion systems generating five and one hundred kilowatts and finally in the megawatt (thousand-kilowatt) range. The government of Puerto Rico has requested NASA to design a windmill for power generation on its island of Culebra.

ELECTRICITY FROM SOLAR THERMAL ENERGY

Many of us have used a magnifying glass to focus sunlight and start a fire. The same principle is used in solar engines in which curved-reflector or lens-type collectors focus the Sun's radiation to intensely heat a fluid. This

heated fluid can drive a turbine (heat) engine. Solar engines such as this ran printing presses and pumped water for irrigation many years ago. Their available temperature was high and their heat was clean. However, they could not compete with modern gasoline engines as long as petroleum was abundant and inexpensive.

Today, NASA is looking into this technique to operate turbines which would drive generators and produce electricity. It is studying collectors, fluids, pipes to carry the fluid, materials, and general systems.

SOLAR CELLS

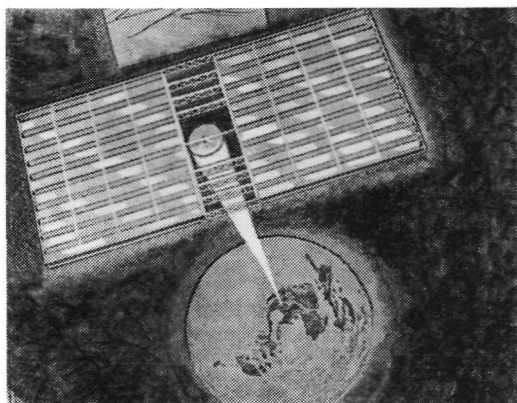
Conversion processes always lose or waste energy. Most processes for generating electricity from solar radiation convert it first to heat which drives an engine that in turn spins a generator. But solar cells can convert light (even on cloudy days) directly into electricity without moving parts.

Solar cells power nearly every NASA spacecraft. They are presently used on Earth in remotely located areas for special tasks where their high cost (about \$50 per watt) is not limiting; for example, automatic weather stations and navigational buoys. They are now too expensive for industrial, residential, or commercial use.

The efficiency of solar cells today is slightly more than 15 percent. NASA is steadily reducing the cost and increasing efficiency of solar cells. Eventually, vast solar cell arrays might be set up in sunny areas as "energy farms". Night-fall would, of course, cut off solar power which would be supplemented with stored energy.

A "solar farm" in geosynchronous orbit could furnish electricity nearly 24 hours a day. In such an equatorial orbit (about 35,680 kilometers or 22,300 miles, above Earth), a satellite takes as long to revolve around Earth as the Earth takes to rotate on its axis.

Thus, the satellite remains more or less fixed over one spot on the surface. The satellite's night would last about $1\frac{1}{4}$ hours. The slack could be taken up by stored energy on Earth during the relatively infrequent and short periods when the satellite is in Earth's shadow (eclipsed by Earth).



A Satellite Solar Power Station (SSPS) big enough to supply a substantial part of the Nation's energy requirements is dependent upon perfecting the Space Shuttle and Space Tug and major advances at least in the technologies of solar cells, microwave systems, and light-weight structures. The Space Shuttle is NASA's planned reusable transport system for taking people, experiments, and equipment between Earth and Earth orbit. The Tug will transfer them, if needed, from the low Shuttle orbit to higher orbits. Many Shuttle and Tug trips would be needed to transport and assemble the parts of an SSPS.

The electricity generated by the SSPS would be converted to ultra high frequency radio waves called microwaves, beamed to appropriate receivers on the ground, and transformed back to electricity for transmission to users. NASA must work: on frequencies

least affected by weather; on minimizing spillover, or waste, of the beam; on efficient conversion techniques; and on avoiding exposure of living things to the beam.

CLEAN AND RENEWABLE FUELS

As noted earlier, it took nature millions of years to create Earth's oil, gas, and coal. Today, science can significantly compress that time scale, converting vegetation by a number of processes into clean-burning oil, gas, or powder (replacing coal in power plants). Land and water plants can be grown specifically for fuel in areas set aside for this purpose.

Among the key goals are development of low-cost techniques for production and collection of organic material and its conversion into fuel. NASA's long experience in hydrocarbon fuels chemistry and combustion would contribute to this effort.

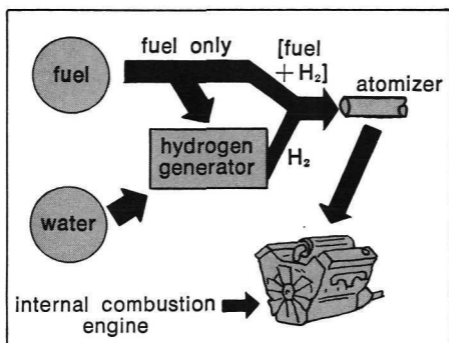
Hydrogen, the most abundant element in the Universe, is the cleanest fuel available. However, it is expensive to produce from any source but fossil fuels.

Solar thermal energy (heat) might be utilized directly to dissociate water into hydrogen and oxygen or indirectly to produce electricity that would in turn electrolyze water into hydrogen and oxygen.

NASA employs hydrogen as a high-energy rocket fuel. Many years ago, NASA's predecessor, the National Advisory Committee for Aeronautics, developed an experimental jet airplane that burned hydrogen rather than conventional jet fuel. NASA is continuing to study use of hydrogen as an aircraft fuel.

A current NASA program is designed to use hydrogen to reduce pollution and increase efficiency in internal combustion engines. The method being explored is injection of hydrogen into gasoline which permits it to burn

at leaner mixtures. The process may be applicable to any hydrocarbon-fueled engine, whether auto or aircraft.



NASA is testing the system with modified Chevrolet four-door sedans equipped with automatic transmissions and power accessories. The program is experimental and still in its early stages.

NASA's Lewis Research Center is studying concepts for hydrogen generators concurrently with tests and development of an entire system at the NASA Jet Propulsion Laboratory, Pasadena, California.

LOCATING ADDITIONAL FUEL DEPOSITS

Both NASA's manned Skylab space station program and unmanned Earth Resources Technology Satellite have helped to prospect for undiscovered hydrocarbon deposits to fill the energy gap while new systems are being developed. The orbital observations may also reveal promising new sites for tapping geothermal energy—heat from the Earth's interior.

Underground heat has long been used by the United States and other countries to produce electricity. However, only a fraction of its potential has been exploited.

MORE EFFICIENT USE OF FUEL

NASA developments in aeronautical technology could permit the next generation of jetliners to achieve a 30 percent or more increase in passenger-kilometers flown per liter of fuel. For example, NASA has been flight testing an aircraft advanced flight control system called digital fly-by-wire. It appears that equipping aircraft with this advanced control system would improve handling qualities for all flight conditions, enhancing flight safety.

Because of its responsiveness, this electronic flight system can be used to reduce aerodynamic and structural loads. In addition, light-weight wires replace the heavy system of metal rods, hinges and hydraulic lines that previously translated the pilot's signals from the aircraft control stick to the aircraft's control surfaces. The total weight reduction can significantly increase passenger and cargo capacity or kilometers flown per liter of gas.

The NASA-developed supercritical wing, a commercial jet transport version of which was recently flight tested, would enable an aircraft to operate about 15 percent more efficiently than it does with a conventional airfoil. Thus, aircraft can use less fuel.

Another NASA design innovation, the antisymmetrical wing, would enable high-speed aircraft to use less fuel than current delta-winged jets both during takeoff and landing and while cruising at 12,000 meters (40,000 feet). The wing crosses the airplane's fuselage at right angles for takeoff and landing and pivots to cross diagonally for high-speed flight.

NASA is also developing and testing composite materials—combinations of metal and plastic such as graphite epoxy—which may reduce aircraft weights by more than 30 percent when compared to aluminum structures.

Other potential economies in aircraft

operations are expected from NASA's work on engines. With new light-weight materials and improved fan design, NASA is paving the way for improved performance and cleanliness in aircraft engines.

In response to a request from the Office of Coal Research, Department of the Interior, NASA is looking into ways to increase the efficiency of electric power-generating plants using coal for fuel. NASA studies are pointing the way not only to substantial fuel savings but also to significant reduction of thermal pollution.

A typical power plant wastes much of coal's heat. The vapor pressures built up in the steam turbine must be held down to avoid blow-out. As a result, only about 35 percent of the coal's heat is used for generating electricity and some 65 percent is vented to the outside air.

NASA is studying topping cycles using liquid metals (for example, molten potassium or sodium) in power plants. In the topping cycle concept, coal heat vaporizes the metal at a high temperature. The metal vapor drives a turbine to generate electricity. The excess (waste) heat from the cycle is then used to produce steam that drives a conventional steam powerplant. By this means, a given amount of electricity can be generated with perhaps 40 percent less fuel.

NASA's Lewis Research Center and the Environmental Protection Agency (EPA) are evaluating the contribution to advanced automotive propulsion that could be made by adapting the Rankine and Brayton energy conversion technologies developed in the aerospace program. In the Rankine cycle, a working fluid such as water is heated to vapor or steam which then drives a turbine. The Brayton system operates with hot gas alone. Theoretically, either system can burn cleaner and provide more

kilometers per liter of fuel than the internal combustion system which drives today's automobiles, while offering equal or better engine life.

They have a number of other potential advantages such as comparative quietness, multi-fuel capability, and minimal vibration. The Department of Transportation and NASA are also studying application of Brayton cycle technology for powering buses and trains.

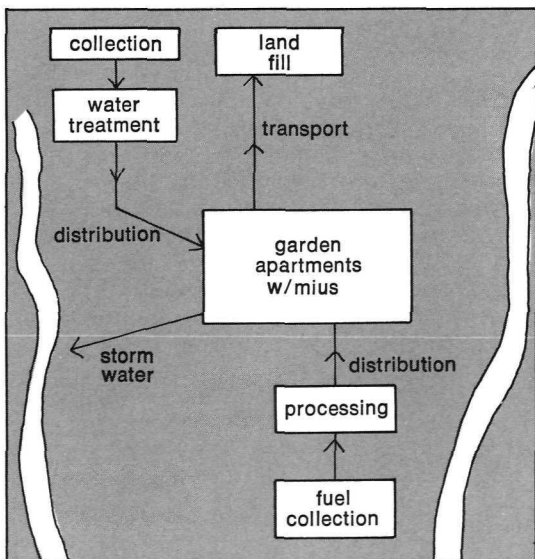
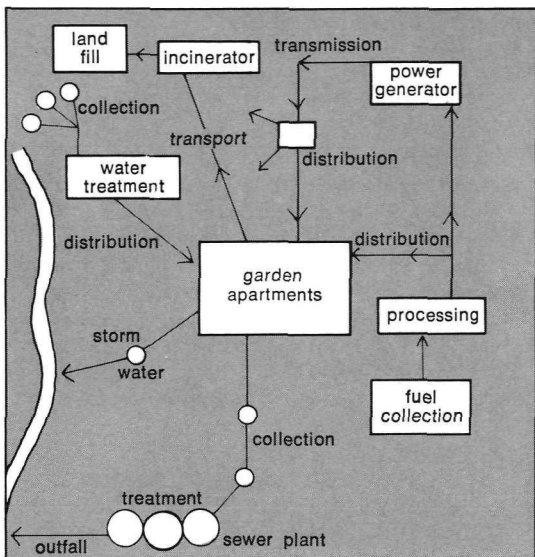
MIUS (MODULAR INTEGRATED UTILITY SYSTEM) CONSERVATION OF FUEL

Manned spacecraft, such as Mercury, Gemini, Apollo, and Skylab, have had independent integrated life support and utility systems. Higher degrees of energy conservation and material recycling are being developed for use on prolonged space missions.

In 1971, NASA conducted a special study to determine how some of the technical approaches and design philosophies for future large space stations could be adapted to a 500-unit garden apartment complex. The design featured combined on-site utility functions in which waste heat from electrical power generation is recovered for space and water heating, air conditioning, and recycling of liquid waste. In addition, on-site incineration of solid waste provides additional heat energy while reducing solid waste to a small amount of noncombustible ash.

This effort led to the Modular Integrated Utility System (MIUS), a joint project of NASA's Lyndon B. Johnson Space Center, Houston, Texas, and the Department of Housing and Urban Development (HUD). The project points the way not only toward savings of more than 30 percent in fuel use, but also to substantial reductions in sewage.

NASA and HUD are conducting design studies to accommodate MIUS



to such facilities as other large-size garden apartments, high-rise apartment complexes and office buildings, a large shopping center, schools, and hospitals.

Climatic variations are taken into account by analyzing how MIUS would be designed for such cities as Houston, Washington, Minneapolis, Denver, and Seattle.

NASA is investigating several advanced subsystems for the MIUS. One of the most promising ideas is pyrolysis, the "destructive distillation" of solid wastes (garbage) into gas or oil that can be collected and stored for later use. This process would significantly reduce the volume of solid waste to be disposed of, while recovering usable energy.

Studies are underway to determine the quantity and quality of gas or oil that can be produced in this way. The preliminary figures indicate that the pyrolysis process may supply as much as ten percent of a community's energy needs.

OCEAN TEMPERATURE DIFFERENTIALS

The ocean collects and stores energy, giving an advantage to an electric power plant fueled by ocean thermal energy. In the Gulf Stream, there is about a 30-to-40 degree difference in temperature between surface water and water at a depth of 600 meters (2000 feet). The difference could operate heat engines which in turn could drive electrical generators.

Tapping the energy of the Gulf Stream could supply all the growing electrical energy needs of the United States as far ahead as 1985 with only a three-tenths of a degree reduction in the temperature of that great warm ocean river. This reduction may be beneficial as it would slightly offset the ocean's thermal pollution (heating up) due to other uses.

NASA expertise is aimed at solving a number of technological problems connected with ocean temperature differential systems. Among these problems are the stresses on pipes and structures that would be caused by ocean currents at various depths flowing at different speeds and sometimes in opposite directions; by storms; by salt-water corrosion; and by the clogging of boiler passageways by debris and ocean life.

The efficiency of a system using ocean temperature differentials to generate electricity would be low because of the relatively small temperature differences. As a result, the system would require huge low-cost equipment to be economically attractive.

HOW SOON?

Sooner than we think if we mount the right kind of effort. Some of the advances could be available in this decade; others, in the eighties. For example, among the conclusions in the NASA-NSF Solar Energy Panel report, "Solar Energy as a National Energy Resource", is the following:

"If solar development programs are successful, building heating could reach public use within five years, building cooling in six to 10 years, synthetic fuels from organic materials in five to eight years, and electricity production in 10 to 15 years.

A number of panel members believe that the new energy sources could be ready even earlier.

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